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ABSTRACT

A teaching procedure and a curriculum construction model known as the learning cycle is described in this paper and research findings are discussed. Questions investigated include: (1) would students achieve more content understanding if taught with the learning cycle or exposition?; (2) would more content retention be evident if measurements were of a multiple choice or of an essay format?; and (3) how would the learning cycle procedures affect the I.Q. measurements of the students? Research findings suggested that the concrete teaching procedure was superior to the formal teacher procedure employed with ninth grade students. Related research results are also reviewed which indicate that students taught by the learning cycle significantly outgained the comparison groups in intellectual development. Explanations are suggested for why the learning cycle functions successfully. References transparencies, and graphs of experimental results are also provided. (ML)

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Curricula Which Promote Reasoning

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One of the great privileges of my career has been the opportunity to work with Dr. Robert Karplus and the Science Curriculum Improvement Study (SCIS). That experience taught me the structure of a teaching procedure and a curriculum construction model which has become known as the learning cycle. For nearly the past twenty years the learning cycle has been the direct and/or tangential focus of a considerable portion of our research. That research has taught us many things which I will describe here. The details of the design of each piece of research will not be described here but since all the research referred to has been published, the details of the designs are available if you are interested.

The Significant Research Dr. Don Stafford and I (10) studied the impact that the SCIS unit Material Objects would have on the acquisition of conservation reasoning by first graders. We found that studying that course for four months markedly increased the conservation reasoning of students over those who experienced first grade science from a textbook

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(transparency used here). That was our first piece of data that led us to hypothesize that the learning cycle promotes reasoning.

Professor Almy of Columbia University has stated that the reasoning used in beginning reading and conservation are similar. That led us to hypothesize that perhaps the Materials_Objects unit could be used to promote reading readiness as measured with the Metropolitan_Reading_Readiness_Test . Dr. Don Kellogg (6) and I conducted a four-month experiment and did indeed find a significant increase in the reading readiness of the children who studied the Material Objects unit (transparency used here). We believe we have indeed shown that curricula can be used to move students into the concrete reasoning period.

The next logical question to ask was whether or not the learning-cycle teaching and curriculum development procedure will allow students to learn more content. Before that research could be begun, however, we had to define what we meant by "more content". With Dr. Anton Lawson's leadership we hypothesized that just as there are concrete and formal levels of thought, there are also concepts which can be rated as requiring concrete or formal thought. We did not know it at the time but Michael Shayer in London was also working on the same problem. Our hypothesis was that those students who used formal

thought could be successful on concrete and formal concepts and those students who used only concrete thought would not be successful on formal concepts.

Concepts were selected from biology, chemistry and physics and rated as concrete or formal and examinations were constructed and content-validated to measure the understandings of those concepts. The examinations were given in the spring of the academic year and the questions covered only content the students had experienced. A total of 133 students participated in the research--50 from biology, 50 from chemistry and all 33 students who were enrolled in physics. (The enrollments in the participating school in chemistry and physics have increased between 100-200 per cent since the learning cycle teaching procedure has been introduced.) The intellectual levels of the 133 students were measured with Piagetian-task interviews. The results were gratifying (4). Concrete operatonal students do not learn formal concepts and formal operational students learn both concept types (transparency used here).

Earlier research had revealed that the thought of ninth grade students was between 80 and 90 per cent concrete operational. We asked several questions:

1. Would students achieve more content understandings if taught with the learning cycle or exposition?
2. Would more content retention be evident if we measured it with multiple choice or free-response (essay) tests?

3. How would the learning cycle procedures affect the I.Q. measurements of the students?

We selected two classes of ninth graders of about 25 students each to secure data to answer our questions. We constructed four units on static electricity, current electricity, light and optics and sound using first the learning cycle teaching procedure and second, the inform, verify and practice teaching procedure,that is,--exposition. This latter group we called the formally taught group and we used oral explanations, motion pictures and filmstrips, a textbook, written questions and problems, supervised study and demonstrations. The learning cycle group--which we called the concretely taught group--was taught using materials in the exploration, conceptual invention, expansion of the idea format. The same teacher, Livingston Schneider, taught both groups and we had prepared both curricula the summer preceding the experiment. The results (9) showed that more intellectual development occurred in the concretely taught group, the language and non-langauge IQ scores in that group diverged while those same IQ scores in the formally taught group converged, and more content retention occurred using essay tests than multiple choice tests. We concluded that for the ninth grade topics used the concrete teaching procedure was superior to the formal teaching procedure.

Some biology students are beginning to move into the formal operational thought period. Our prior research had shown that biology students were mainly in the concrete

operational and transition-to-formal stages of intellectual development. To further test the efficiency of the learning cycle teaching and curriculum construction plan, we elected to study biology teaching and do so in a rural setting. The intellectual development levels of the 126 participating students were measured and the group which was to experience the formal instruction--exposition--consisted of 29 who reasoned at the concrete operational level, 28 in transition to the formal level and five formal operatonal students. The group who was to experience the learning cycle was composed of 30 concrete operational reasoners and 34 students in transition to formal thought. Although data were gathered on the formal operational students no interpretations were made of those data because of the small number.

In the ninth grade experiment the same teacher taught both the learning cycle and exposition groups. We wanted to test the teacher variable so in the biology experiment a teacher who was firmly committed to the exposition formal teaching procedure taught that group and the teacher-researcher taught the learning cycle groups (5). The formal teacher selected the concepts to be taught, the specific concepts for the content examinations and the three dates from September through April when those examinations would be given--those dates represented the three evaluation points of the experiment (transparencies used here). The researchers categorized the concepts as to concrete or formal and prepared learning cycles to teach each one.

There is an important hypothesis to be tested here which stems from the Lawson-Renner research and because of the paucity of formal operational thinkers at the ninth grade level testing that hypothesis was not possible there. Lawson and Renner found that concrete operational students do not learn formal concepts. In that case the manner in which they are taught should not matter; they won't learn the content anyway. On the three evaluation points, the group taught formal concepts formally achieved percentages of success on the formal concept of 22, 19, and 29 respectively while the group taught formal concepts with the learning cycle received percentages of success of 25, 24, and 32 respectively. While the percentage of success of the learning cycle group on formal learning concepts is slightly higher than the formally taught group, it is not statistically significantly so.

Success of the concrete and formally taught groups on the concrete concepts is another story. On all three evaluation examinations the group who experienced the learning cyce instructional procedure for outgained the group who experienced the formal instruction procedure. The results on all three evaluation examinations were statistically significant at the 0.001 level. The learning-cycle taught group also significantly outgained the exposition taught group on intellectual development (transparency used here).

An Interpretation . The research done by my colleagues Tony Lawson, Don Stafford, Don Kellogg, Livingston Schneider and Roger Purser and I seems to suggest these things.

1. Concrete operational students do not learn formal concepts.
2. The learning cycle in a teaching procedure and curriculum construction model which encourages students to move from one intellectual level to another.
3. The learning cycle encourages students to develop deeper understandings of the content being taught.
4. When trying to teach formal concepts to concrete operational reasoners, the teaching procedures used is probably unimportant.

Why Does the Learning Cycle Function Successfully? There are probably many answers to that question but basically, I believe it is because it comes from an educational and scientific theory base. In 1961 (1) the Educational Policies Commission stated that the central purpose of schools is to teach students to think. That group defined the essense of the ability to think as the rational powers of the free mind and identified the rational powers as recalling, imagining, classifying, generalizing, comparing, evaluating, analyzing, synthesizing, deducing and inferring. The second part of the theory base for the learning cycle deals with the structure of the discipline of science. There are many descriptions of that discipline (transparencies used here). Figure 1 shows three of those definitions from well known scientists and one science historian. Each of those descriptions emphasizes that not only does science consist of knowledge and information but it also must have an organizational component that helps interpret and make sense of the knowledge. Of all the descriptions given, I like best the short, succinct description of Duane Roller: "Science is the quest for knowledge, not the knowledge itself". Not much analyzing, sythesizing, inferring and using the other

rational powers needs to be done to ascertain that the rational powers are needed in implementing every part of each of the descriptions of science given in Figure 1.

Furthermore, the descriptions of science call for experiences. Initial experience with scientific ideas is what the exploration phase of the learning cycle is designed to provide. The descriptions also call for a reduction to an order of the data that experience provides. That, of course, is the conceptual invention phase of the learning cycle. The last phase of the learning cycle--which we call the expansion of the idea--is not inherent in the description of science given here. We added it because Robert Karplus believed that students should discover what the newly developed concept is good for where it can be used and, most importantly, what else can be found using that concept.

We believe, therefore, that the learning cycle teaches science as science is structured. Furthermore, the learning cycle is compatible with the developmental learning model of Jean Piaget (7). Assimilation occurs during exploration, accommodation occurs during conceptual invention and concept organization occurs during the expansion of the idea phase. So the theory base upon which the learning cycle teaching and curriculum development models are based has its roots in science, educational purpose, and developmental learning. In order, however, to have maximum success with the learning cycle teaching procedure, the intellectual level of the concepts must be matched with the intellectual levels of the students. We

WHAT IS SCIENCE?

THE OBJECT OF ALL SCIENCE IS TO COORDINATE OUR EXPERIENCES AND BRING THEM INTO A LOGICAL SYSTEM (2).--ALBERT EINSTEIN

THE TASK OF SCIENCE IS BOTH TO EXTEND THE RANGE OF OUR EXPERIENCE AND REDUCE IT TO ORDER (2).--NIELS BOHR

SCIENCE IS BUILT UP WITH FACTS, AS A HOUSE IS WITH STONES, BUT A COLLECTION OF FACTS IS NO MORE A SCIENCE THAN A HEAP OF STONES IS A HOUSE (3).--HENRI POINCAIRE

SCIENCE IS THE QUEST FOR KNOWLEDGE, NOT THE KNOWLEDGE ITSELF (8).--DUANE ROLLER

FIGURE 1

have prepared science courses for grades one through twelve and have been gratified by the success in the public school which serves as our laboratory.

In closing, I would like to pose a question. We know that concrete students do not learn formal concepts. What could be done to those formal concepts to let concrete students begin to learn them? Can those concepts be dissected in some manner so concrete students can learn portions of them? Or do formal concepts have the property of the structured whole which Piaget describes? Our recent research with eight graders leads us to hypothesize that the concrete student--formal concept questions needs to be investigated because our recent data suggest that the proportion of concrete thought leaving our schools is probably increasing.

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SUCCESS OF THE INSTRUCTIONAL GROUPS ON CONCRETE CONCEPTS

	Concrete Instruction	Formal Instruction
Test #1	68%	49%
	$p < 0.001$	
Test #2	62%	42%
	$p < 0.001$	
Test #3	56%	42%
	$p < 0.001$	

10th Grade B

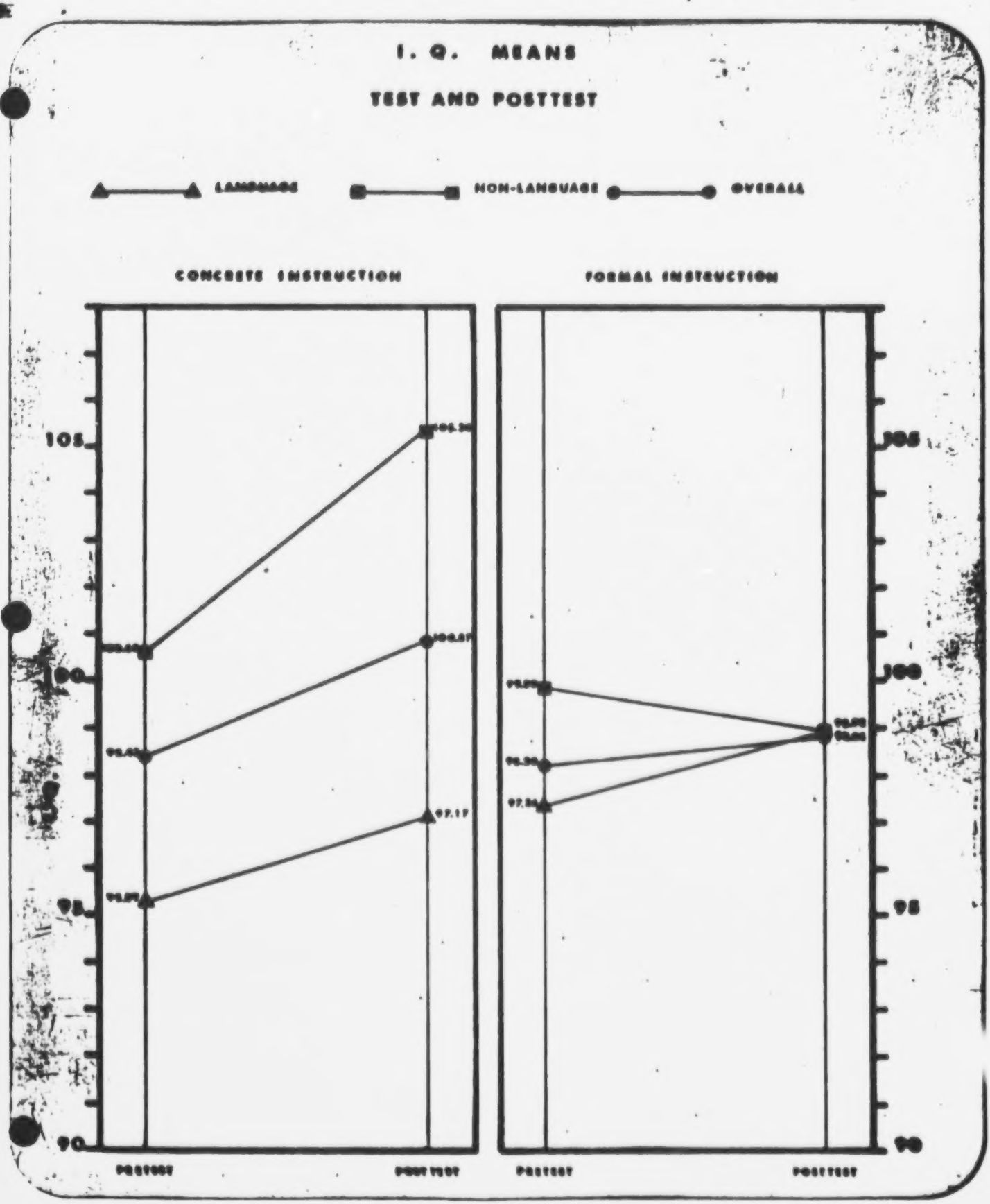
SUCCESS OF THE INSTRUCTIONAL GROUPS ON FORMAL CONCEPTS

	Concrete Instruction	Formal Instruction
Test #1	25%	22%
	p = 0.09	
Test #2	24%	19%
	p = 0.10	
Test #3	32%	29%
	p = 0.38	

9th Grade Physical Science

I. Q. MEANS

TEST AND POSTTEST



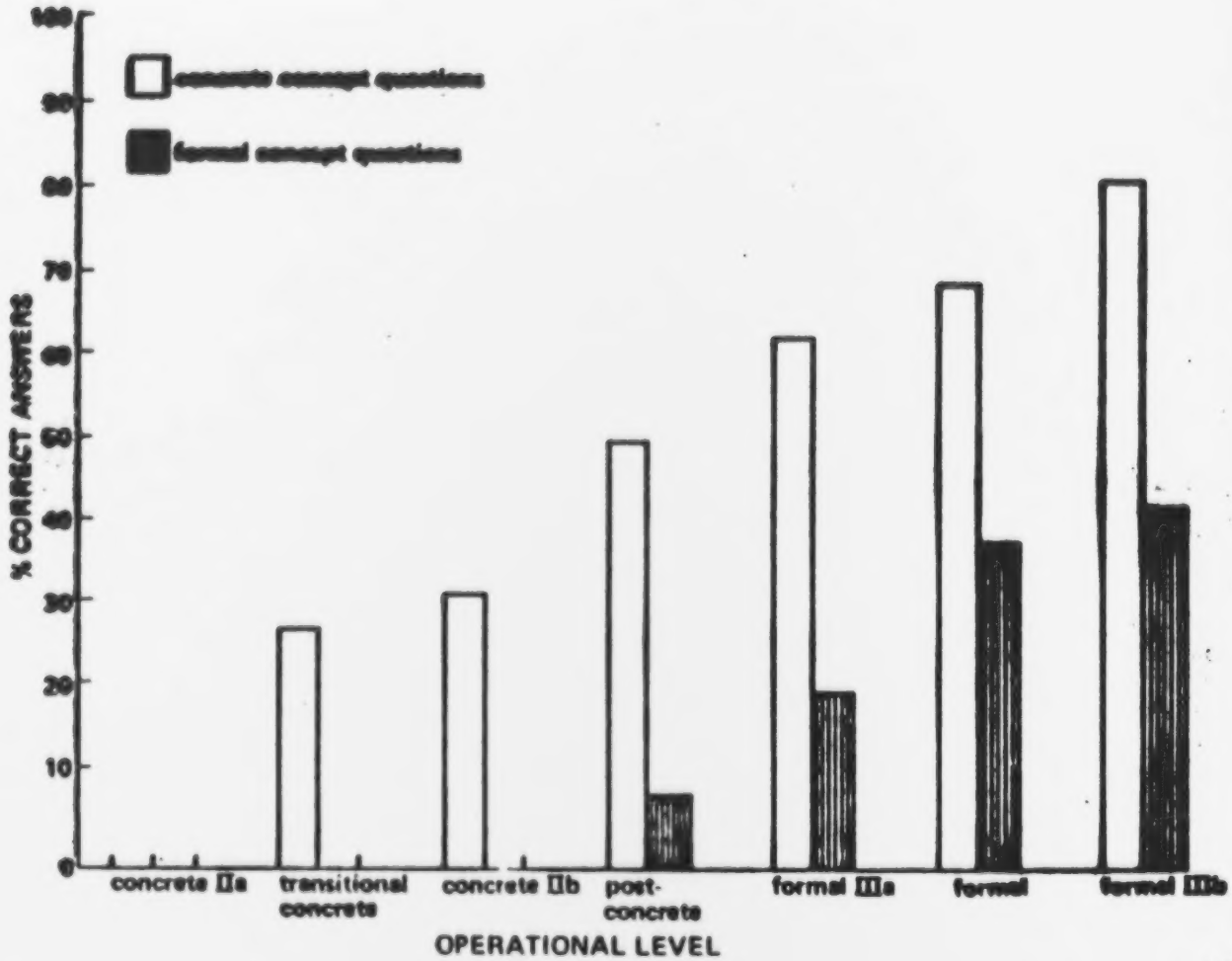
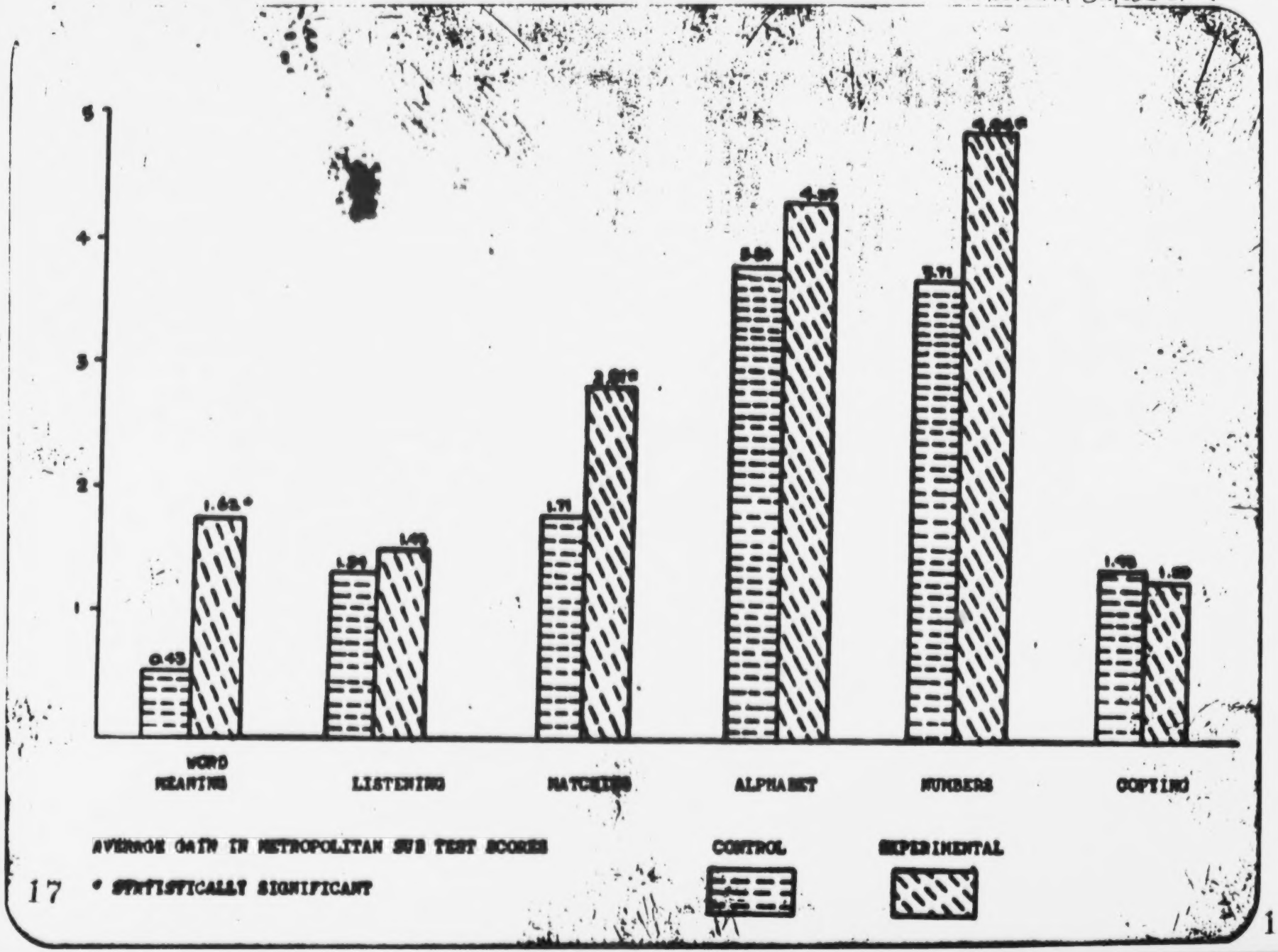
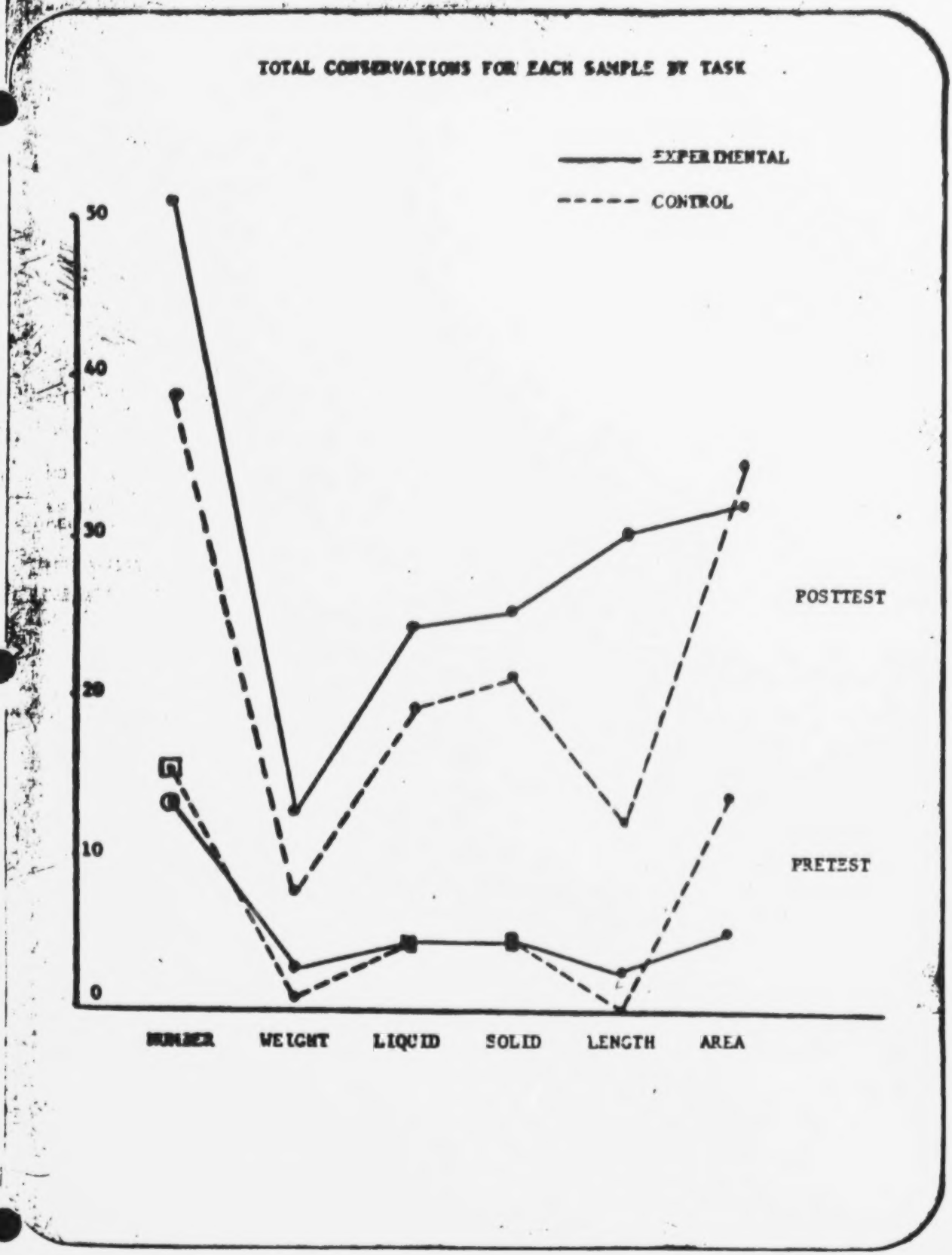


Fig. 1. Relationship between levels of student functioning and success on concrete and formal concept questions. The data shown indicate that students do not experience any success with formal concepts until they have left the concrete thought stage and have entered that transitional period (postconcrete) leading to entry into the formal thought period. Even then, success is limited.

First Grade SCI Using Ready Natural Object Unit





Conservation results by Material/Object